Key

xtra Practice – Topic 8 IB Chem I

1. Define the terms *acid* and *base* according to the Brønsted-Lowry theory **and** state **one** example of a weak acid and **one** example of a strong base.

- acid - proton/H^+ donor — HCl, HNO_3, H_2SO_4 etc
- base - proton/H^+ acceptor — $NaOH$, KOH, $Ca(OH)_2$ etc

2. Describe **two** different methods, one chemical and one physical, other than measuring the pH, that could be used to distinguish between carbonic acid and hydrochloric acid of the same concentration.

for stronger acid (HCl): → chemical: fast reaction w/ Mg metal — more H_2 gas produced
→ physical: ↑ conductivity

3. Black coffee has a pH of 5 and toothpaste has a pH of 8. Identify which is more acidic **and** deduce how many times the $[H^+]$ is greater in the more acidic product.

Coffee = acidic

5 6 7 8

10 100 1000× $[H^+]$ difference

4. Explain, using the Brønsted-Lowry theory, how water can act either as an acid or a base. In **each** case identify the conjugate acid or base formed.

as acid → $H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$ (H_2O: Base; H_3O^+: conjugate acid; OH^-: conjugate base)

5. Water dissociates according to the following equation.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

-State the equilibrium constant expression for the dissociation of water.

$K_w = [H^+][OH^-]$ or $K_w = [H_3O^+][OH^-]$

-Explain why even a very acidic aqueous solution still has some OH^- ions present in it.

↳ autoionization of water causes OH^- / H_3O^+ to be formed

Fill in the following table.

	Acid	Base	Conjugate Acid	Conjugate Base	Equation
9	HNO_2	H_2O	H_3O^+	NO_2^-	$HNO_2 + H_2O \rightarrow NO_2^- + H_3O^+$
10	H_2O	F^-	HF	OH^-	$H_2O + F^- \rightarrow HF + OH^-$
11	HCN	NH_3	NH_4^+	CN^-	$NH_3 + HCN \rightarrow NH_4^+ + CN^-$
12	$HClO_3$	OH^-	H_2O	ClO_3^-	$HClO_3 + OH^- \rightarrow H_2O + ClO_3^-$
13	HSO_4^-	PO_4^{3-}	HPO_4^{2-}	SO_4^{2-}	$HSO_4^- + PO_4^{3-} \rightarrow SO_4^{2-} + HPO_4^{2-}$
14	H_2O	S^{2-}	HS^-	OH^-	$S^{2-} + H_2O \rightarrow OH^- + HS^-$
15	HCO_2H	OH^-	H_2O	HCO_2^-	$HCO_2H + OH^- \rightarrow H_2O + HCO_2^-$

arrows not representative

16. Write an equation that shows the reaction of ammonia, NH_3 with hydrobromic acid, HBr. Label the acid, the base, the conjugate acid, and the conjugate base.
17. Write an equation that shows the reaction of phosphate ion, PO_4^{3-}, reacting with hydronium ion, H_3O^+. Label the acid, the base, the conjugate acid, and the conjugate base.
18. Write an equation that shows the reaction of hydrogen sulfide, HS^- with hydroxide ion, OH^-. Label the acid, the base, the conjugate acid, and the conjugate base.

16. NH_3 (base) + HBr (acid) $\rightleftharpoons$ NH_4^+ (conj acid) + Br^- (conj base)

17. PO_4^{3-} (base) + H_3O^+ (acid) $\rightleftharpoons$ H_2O (conj base) + HPO_4^{2-} (conj acid)

18. HS^- (acid) + OH^- (base) $\rightleftharpoons$ H_2O (conj acid) + S^{2-} (conj base)

KEY

Chemistry: *pH and pOH calculations*

Part 1: Fill in the missing information in the table below.

pH	[H_3O^{1+}]	pOH	[OH^{1-}]	ACID or BASE?
3.78	1.66×10^{-4} M	10.22	6.03×10^{-11} M	Acid
3.41	3.89×10^{-4} M	10.59	2.57×10^{-11} M	Acid
8.81	1.55×10^{-9} M	5.19	6.46×10^{-6} M	Base
8.69	2.04×10^{-9} M	5.31	4.88×10^{-6} M	Base
8.46	3.47×10^{-9} M	5.54	2.88×10^{-6} M	Base
12.1	8.45×10^{-13} M	1.90	1.26×10^{-2} M	Base
11.86	1.38×10^{-12} M	2.14	7.24×10^{-3} M	Base
3.40	3.98×10^{-4} M	10.6	2.31×10^{-11} M	Acid
10.91	1.23×10^{-11} M	3.09	8.13×10^{-4} M	Base
5.13	7.49×10^{-6} M	8.87	1.35×10^{-9} M	Acid
4.06	8.71×10^{-5} M	9.94	1.15×10^{-10} M	Acid
6.41	3.89×10^{-7} M	7.59	2.57×10^{-8} M	Acid
4.16	6.92×10^{-5} M	9.84	1.45×10^{-10} M	Acid
0.98	1.06×10^{-1} M	13.0	1.00×10^{-13} M	Acid
10.18	6.61×10^{-11} M	3.82	1.51×10^{-4} M	Base
7.93	1.17×10^{-8} M	6.07	8.53×10^{-7} M	Base
7.05	8.91×10^{-8} M	6.95	1.12×10^{-7} M	~Base
9.33	4.73×10^{-10} M	4.67	2.14×10^{-5} M	Base
12.67	2.14×10^{-13} M	1.33	4.68×10^{-2} M	Base
12.0	1.0×10^{-12} M	2.01	9.87×10^{-3} M	Base
11.68	2.09×10^{-12} M	2.32	4.79×10^{-3} M	Base
7.04	9.22×10^{-8} M	6.96	1.10×10^{-7} M	~Base
1.76	1.74×10^{-2} M	12.24	5.75×10^{-13} M	Acid
2.70	2.00×10^{-3} M	11.3	5.39×10^{-12} M	Acid

Part 2: *For each of the problems below, assume 100% dissociation.*

1. A. Write the equation for the dissociation of hydrochloric acid.

$$HCl(aq) \rightarrow H^{1+}(aq) + Cl^{1-}(aq)$$

B. Find the pH of a 0.00476 M hydrochloric acid solution.

$$\underset{0.00476\ M}{HCl(aq)} \rightarrow \underset{0.00476\ M}{H^{1+}(aq)} + Cl^{1-}(aq)$$

$$pH = -\log[H^+]$$
$$pH = -\log[0.00476\ M]$$
$$pH = 2.32$$

2. A. Write the equation for the dissociation of sulfuric acid.

$$H_2SO_4(aq) \rightarrow 2\,H^{1+}(aq) + SO_4^{2-}(aq)$$

B. Find the pH of a solution that contains 3.25 g of H_2SO_4 dissolved in 2.75 liters of solution.

$$\text{Step 1: } x\ mol\,H_2SO_4 = 3.25\ g\,H_2SO_4\left(\frac{1\ mol\,H_2SO_4}{98\ g\,H_2SO_4}\right) = 0.033\ mol\,H_2SO_4$$

$$\text{Step 2: } M = \frac{mol}{L} \Rightarrow M = \frac{0.033\ mol\,H_2SO_4}{2.75\ L} \Rightarrow M = 0.0121\,M\,H_2SO_4$$

$$\text{Step 3: } H_2SO_4(aq) \rightarrow 2H^+ + SO_4^{2-}(aq)$$
$$0.0121\,M \quad \therefore 0.0242M$$

$$\text{Step 4: } pH = -\log[H^+] \Rightarrow pH = -\log[0.0242\ M] \Rightarrow pH = 1.62$$

3. A. Write the equation for the dissociation of sodium hydroxide.

$$\underset{0.000841\ M}{NaOH(aq)} \rightarrow Na^{1+}(aq) + \underset{0.000841\ M}{OH^{1-}(aq)}$$

B. Find the pH of a 0.000841 M solution of sodium hydroxide.

$$pOH = -\log[OH^-]$$
$$pOH = -\log[0.000841\,M]$$
$$pOH = 3.08$$

$$pH + pOH = 14$$
$$pH + 3.08 = 14$$
$$pH = 10.92$$

or

$$K_w = [H^+][OH^-]$$
$$1\times10^{-14} = [H^+][0.000841\,M]$$
$$[H^+] = [1.19\times10^{-11}\ M]$$

$$pH = -\log[H^+]$$
$$pH = -\log[1.19\times10^{-11}\ M]$$
$$pH = 10.92$$

***Part 2:* continued**

4. A. Write the equation for the dissociation of aluminum hydroxide.

$$\underset{2.36\times10^{-5}\ M}{Al(OH)_3(aq)} \rightarrow Al^{3+}(aq) + \underset{7.08\times10^{-5}\ M}{3\ OH^{1-}(aq)}$$

B. If the pH is 9.85, what is the concentration of the aluminum hydroxide solution?

$$pH + pOH = 14$$
$$9.85 + pOH = 14$$
$$pOH = 4.15$$

$$pOH = -\log[OH^-]$$
$$4.15 = -\log[OH^-]$$
$$\boxed{2^{nd}}\ \boxed{\log}\ -4.15 = [OH^-]$$
$$[OH^-] = 7.08\times10^{-5}\ M$$

$$\frac{7.08\times10^{-5}\ M}{3} = 2.36\times10^{-5}\ M$$

5. A. Write the equation for the dissociation of calcium hydroxide.

$$\underset{2.18\times10^{-3}\ M}{Ca(OH)_2(aq)} \rightarrow Ca^{2+}(aq) + \underset{4.37\times10^{-5}\ M}{2\ OH^{1-}(aq)}$$

B. If the pH is 11.64 and you have 2.55 L of solution, how many grams of calcium hydroxide are in the solution?

$$pH + pOH = 14$$
$$11.64 + pOH = 14$$
$$pOH = 2.36$$

$$pOH = -\log[OH^-]$$
$$2.36 = -\log[OH^-]$$
$$\boxed{2^{nd}}\ \boxed{\log}\ -2.36 = [OH^-]$$
$$[OH^-] = 4.37\times10^{-3}\ M$$

$$2\overline{)4.37\times10^{-3}\ M}\quad \frac{2.18\times10^{-3}\ M}{}$$

$$M = \frac{mol}{L} \Rightarrow 2.18\times10^{-3}\ M \Rightarrow \frac{x\ mol\ Ca(OH)_2}{2.55\ L} \Rightarrow x = 5.57\times10^{-3}\ mol\ Ca(OH)_2$$

$$x\ g\ Ca(OH)_2 = 5.57\times10^{-3}\ mol\left(\frac{74\ g\ Ca(OH)_2}{1\ mol\ Ca(OH)_2}\right) = 0.412\ g\ Ca(OH)_2$$

pH and pOH

1a. $HCl(aq) \rightarrow H^{1+}(aq) + Cl^{1-}(aq)$

b. $\underset{\textbf{0.00476 M}}{HCl(aq)} \rightarrow \underset{\textbf{0.00476 M}}{H^{1+}(aq)} + Cl^{1-}(aq)$

$pH = -\log[H^+]$

$pH = -\log[0.00476\,M]$

$pH = 2.32$

Step 1: $x\,mol\,H_2SO_4 = 325\,g\,H_2SO_4\left(\frac{1\,mol\,H_2SO_4}{98\,g\,H_2SO_4}\right) = 0.03\,mol\,H_2SO_4$

Step 2: $M = \frac{mol}{L} \Rightarrow M = \frac{0.03\,mol\,H_2SO_4}{2.75\,L} \Rightarrow M = 0.01M\,H_2SO_4$

2a. Step 3: $H_2SO_4(aq) \rightarrow 2H^+ + SO_4^{2-}(aq)$

$0.01M \quad \therefore 0.02\,M$

Step 4: $pH = -\log[H^+] \Rightarrow pH = -\log[0.02\,M] \Rightarrow pH = 1.70$

3. $\underset{\textbf{0.000841 M}}{NaOH(aq)} \rightarrow Na^{1+}(aq) + \underset{\textbf{0.000841 M}}{OH^{1-}(aq)}$

$pOH = -\log[OH^-]$

$pOH = -\log[0.000841\,M]$

$pOH = 3.08$

$pH + pOH = 14$

$pH + 3.08 = 14$

$pH = 10.92$

or

$K_w = [H^+][OH^-]$

$1\times10^{-14} = [H^+][0.000841\,M]$

$[H^+] = [1.19\times10^{-11}\,M]$

$pH = -\log[H^+]$

$pH = -\log[1.19\times10^{-11}\,M]$

$pH = 10.92$

4. $\underset{\textbf{2.36x10}^{-5}\textbf{ M}}{Al(OH)_3(aq)} \rightarrow Al^{3+}(aq) + 3\,\underset{\textbf{7.08x10}^{-5}\textbf{ M}}{OH^{1-}(aq)}$

$pH + pOH = 14$

$9.85 + pOH = 14$

$pOH = 4.15$

$pOH = -\log[OH^-]$

$4.15 = -\log[OH^-]$

$2^{nd}\ \log\ -4.15 = [OH^-]$

$[OH^-] = 7.08\times10^{-5}\,M$

$\frac{7.08\times10^{-5}\,M}{3} = 2.36\times10^{-5}\,M$

5. $\underset{\textbf{2.18x10}^{-3}\textbf{ M}}{Ca(OH)_2(aq)} \rightarrow Ca^{2+}(aq) + 2\,\underset{\textbf{4.37x10}^{-5}\textbf{ M}}{OH^{1-}(aq)}$

$pH + pOH = 14$

$11.64 + pOH = 14$

$pOH = 2.36$

$pOH = -\log[OH^-]$

$2.36 = -\log[OH^-]$

$2^{nd}\ \log\ -2.36 = [OH^-]$

$[OH^-] = 4.37\times10^{-3}\,M$

$2\overline{)4.37\times10^{-3}\,M}\ \ 2.18\times10^{-3}\,M$

$M = \frac{mol}{L} \Rightarrow 2.18\times10^{-3}\,M \Rightarrow \frac{x\,mol\,Ca(OH)_2}{L} \Rightarrow x = 5.57\times10^{-3}\,mol\,Ca(OH)_2$

$x\,g\,Ca(OH)_2 = 5.57\times10^{-3}\,M\left(\frac{74\,g\,Ca(OH)_2}{1\,mol\,Ca(OH)_2}\right) = 0.412\,g\,Ca(OH)_2$